CUYAHOGA VALLEY NATIONAL PARK
2001 LONG-TERM ECOLOGICAL MONITORING (VEGETATION) REPORT

Covering the period from summer 1998 through summer 2001

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SUMMARY

Monitoring of the 90 long-term ecological monitoring sites in the park for changes over the past three years has provided valuable information about the health and status of CVNP's natural vegetation. Upland forests of the park with lower deer impacts which were unaffected by gypsy moth defoliation are generally developing as would be expected under natural conditions, with the notable exception of vertical foliage profile, which seems to be decreasing. Upland forests of the park in high deer impact areas which were unaffected by gypsy moth defoliation appeared to be in declining condition, with decreases in seedling abundance, seedling stocking, shrub cover, groundcover diversity, and the vertical foliage profile. The condition of the bottomland forests, regardless of level of deer impact, is generally comparable to the condition of the high deer impact areas of the upland forests. It is noted that in general, the effects of gypsy moth defoliation at least partially counter-balances deer impacts, while magnifying them in some cases, such as facilitating increases in the spread of exotic plants.

Fields were not analyzed for deer impacts due to an inadequate sample size. They seem to be developing properly, except that the vertical foliage profile is decreasing rather than increasing.

A sequence of damage due to deer impacts and recovery from those impacts is postulated as follows:

1. Decreases in vertical structure and groundcover diversity;
2. Decrease in height of the tallest seedlings;
3. Significant decreases in seedling numbers and species composition;
4. Decrease in shrub abundance;
5. Elimination of tree seedlings.

This sequence can continue until some species of plants are eliminated, and all seedling regeneration fails. Assuming some relief from browsing pressure before that point is reached, the plant communities would generally recover in the following sequence:

1. Seedling height growth;
2. Seedling abundance and seedling species composition;
3. Shrub abundance;
4. Vertical structure;
5. Groundcover diversity.

Recommendations are:

1. Data from this project should be mapped and analyzed in conjunction with 2001 and 2002 deer distribution and density data to investigate connections between deer density and deer impacts when that data becomes available;
2. Reasonable means of preventing and ameliorating excessive deer impacts to native vegetation and plant communities should be investigated; and
3. LTEM monitoring should be continued on a cycle of re-measurement every three years.

I. INTRODUCTION

During the summer of 1998, 92 permanent long-term ecological monitoring (LTEM) sites were installed throughout Cuyahoga Valley National Park (CVNP), on federal, Cleveland Metroparks, and MetroParks, Serving Summit County land. The monitoring scheme was designed to address multiple objectives including to:

1. Establish a general framework and quantitative baseline vegetation information on a broad spatial scale representing the plant communities of CVNP to support future experimental research;
2. Monitor for changes in composition, structure, and regeneration of plant communities over time;
3. Identify and interpret changes that may occur as a result of natural succession, management activities, or perturbations such as exotic species, weather events, and grazing pressure;
4. Provide accurate information about vegetation communities in order to accomplish the management directives of the National Park Service (NPS 1998).

A. METHODS

Monitoring design and methods are fully explained in the Long Term Ecological Monitoring (Vegetation) Plan (USDI 1998), and the Long Term Ecological Monitoring (Tree Regeneration) Plan (USFS 1998). These plans outline collection methods for 57 environmental variables at each of the LTEM sites. The variables can be broken into four main categories, overstory, groundcover, tree regeneration, and vertical structure. The sites were first measured in the spring and summer of 1998. In 1999 bottomland forest sites were again studied. In 2001, all sites (except two sites that were destroyed by construction or mowing activity) were measured for all variables except overstory variables, which are only planned for re-measurement every 9 years, or in the event of major overstory mortality (USFS 1998).

In order to account for environmental conditions and perturbations, the sites were classified based on dominant plant physiognomy (forest or field) and forested sites were further differentiated based on landscape position (upland or bottomland), as well as levels of deer impact to seedling height growth and gypsy moth defoliation levels.

Data from the forested sites were analyzed for differences due to white-tailed deer browsing and gypsy moth defoliation based on classification as high and lower deer impact areas and classification of the level of gypsy moth defoliation present on the site. Gypsy moth defoliation between 1998-2000 was identified from GIS coverages prepared based on infrared aerial photographs of the park, as well as from observations of gypsy moth defoliation during the 1998 LTEM data collection. Those sites with defoliation levels identified on the 1998 LTEM data sheets, and those LTEM plots located in defoliated areas identified on aerial photographs were categorized as Undefoliated, Low, Medium, or High gypsy moth defoliation sites based on ocular estimates of canopy damage. The deer impact classification (high or lower) was based on recent analysis of experimental deer exclosure data collected in the park (NPS 2002). The Exclosure Report recommended that change in height of the tallest seedling over time be used to identify high and lower deer impact areas. This was accomplished by calculating the change in height of the tallest seedling between 1998 and 2001 and assigning all sites with no changes or negative changes to the high impact stratum. Care was taken to identify sites in which the height differences were due to apparent non-deer related causes such as the former tallest seedling growing into the sapling class (greater than 2.5 cm diameter at

Summary of Variables

Variable	Description
Height of tallest seedling	Height of Tallest seedling in cm
Seedlings/ha A	seedlings per hectare between 5-30 cm tall
Seedlings/ha B	seedlings per hectare between 30cm and 1m tall
Seedlings/ha C	seedlings per hectare between 1-1.5 m tall
Seedlings/ha D	seedlings per hectare greater than 1.5 m and less than 2.5 cm dbh
Total Seedlings/ha	seedlings per hectare
Weighted Seedlings/ha	seedlings per hectare calculated according to the following formula : Seedlings/ha A + 2(seedlings/HA B)+ 15(seedlings/ha C)+30(seedlings/ha D)
Stocking to sustain low deer impacts	percent of plots per site with more than 10 weighted seedlings (threshold met if 67% of plots per site meet this criteria)
Stocking to sustain high deer impacts	percent of plots per site with more than 30 weighted seedlings (threshold met if 67% of plots per site meet this criteria)
Red Maple Seedlings/site	Number of Red Maple seedlings per site
Sugar Maple Seedlings/site	Number of Sugar Maple seedlings per site
White AshSeedlings/site	Number of White Ash seedlings per site
Black Cherry Seedlings/site	Number of Black Cherry seedlings per site
Browse Hits	Number of browsed plants encountered along groundcover transects
Reproductive plants	Number of Reproductive hits along groundcover transects
Grass/Sedge	Number of Grass/sedge hits along groundcover transects
Seedling hits	Seedling hits along along groundcover transects
Shrub/sapling hits	Shrub hits along along groundcover transects
Number of Species	number of species along groundcover transects
Percent Canopy	percent overstory canopy as measured by the mean of four sperical densiometer readings at three polts per site
Total Plant Hits	Number of plant hits along groundcover transects
Shannon-Weaver Diversity Index	negative log of the sum of the proportional abundances of each species at a site divided by the total abundance of plants on a site
Native Diversity Index	Shannon diversity calculated using only native species
Vertical Foliage Score	Sum of all height strata on all plots at a site, three cover board readings per site, scored as 0-20% cover =1, 21-40% cover =2, 41-60% cover =3, 61-80% cover =4, 81-100% cover =5.
Vertical Foliage A	Sum of all plots at a site; height stratum: between 0 and .5m; score 0-20% cover =1, 21-40% cover =2, 41-60% cover =3, 61-80% cover =4, 81-100% cover =5.
Vertical Foliage B	Sum of all plots at a site; height stratum: between .5m and 1m height stratum;score 0-20% cover =1, 21-40% cover =2, 41-60% cover =3, 61-80% cover =4, 81-100% cover =5.
Vertical Foliage C	Sum of all plots at a site; height stratum :between 1m and 1.5 m height stratum;score 0-20% cover =1, 21-40% cover =2, 41-60% cover =3, 61-80% cover =4, 81-100% cover =5.
Vertical Foliage D	Sum of all plots at a site; height stratum: between 1.5. and 2m height stratum;score 0-20% cover =1, 21-40% cover =2, 41-60% cover =3, 61-80% cover =4, 81-100% cover =5.
Vertical Foliage E	Sum of all plots at a site; height stratum: greater than 2m height stratum;score 0-20% cover =1, 21-40% cover =2, 41-60% cover =3, 61-80% cover =4, 81-100% cover =5.

Table 1

breast height). In such cases, that site was assigned to the lower deer impact group. Fields were not analyzed for differences due to deer because additional stratification resulted in inadequate sample sizes for statistical analysis. Fields were not analyzed for gypsy moth impacts due to a lack of canopy trees on those sites. Differences due to deer impacts were analyzed for variables are described in Table 1.

Groundcover composition and browse data from 1998 were used to determine spring season deer feeding preferences in the forests of CVNP. Since deer feeding preferences may shift as browsing intensity increases (Kohlmann & Risenhoover 1994), it was assumed that since browse has increased significantly over the study period, that the 1998 data would more accurately display the preferences of deer than the 2001 data which were collected during a time when deer browse was significantly elevated.

Spring Deer Feeding Preferences in Forests Based on 1998 Groundcover Transect Data

Species	Abundance	browse	Relative abundance	Relative browse	Proportional browse	Centered Proportional Browse	Preference Index
Rubus spp.	111	12	0.07615879	0.212767094	5.160522399	4.516785862	50.13632307
Rosa multiflora	60	3	0.040820476	0.135416667	6.612585259	5.968848722	35.81309233
Ligustrum vulgare	37	6	0.098889544	0.59375	6.004173692	5.360437155	19.83361747
Viburnum spp.	119	17	0.13151806	0.28757764	2.186601893	1.542865356	18.36009773
Carpinus caroliniana	14	1	0.070840742	0.111111111	1.568463406	0.924726869	1.294617616
Fraxinus spp.	126	8	0.098337563	0.07293956	1.266187211	0.622450674	0
Prunus spp.	110	10	0.124624445	0.095882937	0.769375032	0.125638495	0
Lindera benzoin	25	2	0.144016213	0.107142857	0.743963856	0.100227319	0
Impatiens	148	6	0.149528503	0.092307692	0.617325061	-0.026411476	0
Gallium	172	2	0.100602165	0.052564103	0.576692377	-0.06704416	0
Polygonatum spp.	11	0	0.036181384	0	0	-0.643736537	-0.708110191
Amphicarpa	13	0	0.034950443	0	0	-0.643736537	-0.836857498
Potentilla spp.	14	0	0.035662235	0	0	-0.643736537	-0.901231152
Geranium maculatum	15	0	0.097385362	0	0	-0.643736537	-0.965604806
Mitchella repens	15	0	0.095713414	0	0	-0.643736537	-0.965604806
Vitis spp.	15	0	0.056432742	0	0	-0.643736537	-0.965604806
Fagus grandifolia	19	0	0.12615233	0	0	-0.643736537	-1.22309942
Crataegus spp.	20	0	0.035661623	0	0	-0.643736537	-1.287473074
Hesperis matronalis	20	0	0.016260126	0	0	-0.643736537	-1.287473074
Parthenocissus quinquefolia	102	1	0.089393765	0.033333333	0.486047316	-0.157689221	-1.608430056
Acer rubrum	26	0	0.04536464	0	0	-0.643736537	-1.673714996
Ostrya virginiana	26	0	0.145075932	0	0	-0.643736537	-1.673714996
Floerkia	29	0	0.104257444	0	0	-0.643736537	-1.866835957
Verbesina	33	0	0.030744143	0	0	-0.643736537	-2.124330572
Lonicera spp.	34	0	0.061597195	0	0	-0.643736537	-2.188704226
Toxicodendron radicans	36	0	0.029891249	0	0	-0.643736537	-2.317451533
Cardamine	42	0	0.071385572	0	0	-0.643736537	-2.703693455
Verbesina alternifolia	43	0	0.03485744	0	0	-0.643736537	-2.768067109
Acer saccharum	46	0	0.122018918	0	0	-0.643736537	-2.96118807
Viola spp.	49	0	0.04182805	0	0	-0.643736537	-3.154309031
Prenanthes spp.	55	0	0.117516696	0	0	-0.643736537	-3.540550954
Arisaema triphyllum	58	0	0.129717406	0	0	-0.643736537	-3.733671915
Geum	126	3	0.074702724	0.019230769	0.318226808	-0.325509729	-4.101422581
Sedges	68	0	0.072036416	0	0	-0.643736537	-4.377408452
Pilea pumila	89	0	0.483200611	0	0	-0.643736537	-5.729255179
Glechoma	109	0	0.140671188	0	0	-0.643736537	-7.016728253
Ferns	117	0	0.066643848	0	0	-0.643736537	-7.531717483
Circaea	165	0	0.092877208	0	0	-0.643736537	-10.62165286
Podophyllum peltatum	200	2	0.25354323	0.021052632	0.083033696	-0.560702841	-11.21405681
Grasses	245	0	0.139582415	0	0	-0.643736537	-15.77154516
Alliaria petiolata	335	0	0.239334636	0	0	-0.643736537	-21.56517399

Green shading indicates highly preferred plants. Tan shading indicates highly avoided plants. Unshaded plants are taken as available.

Table 2

Groundcover data from forested plots (data from all forested plots except one were analyzed. Site number 85, was excluded as 90 percent of the site's vegetation was *Alliaria petiolata*, an invasive species. In spite of the large groundcover of this species, a very small percentage of the plant was browsed. The plant was not browsed on any other site, and hence data from this site were deemed atypical and ignored for purposes of determining preferences) were examined by calculating the relative abundance of each species present on each site, calculating the relative browse for each plant species on the site, dividing the relative browse by the relative abundance of that species on each site. This calculation would result in an average proportional browse near 1.00 for species that are browsed in proportion to their abundance, while the number would be greater than 1.00 for those species that are browsed in a greater proportion than the relative abundance; for instance, a species browsed twice as frequently as it occurs in the population would score a 2.00 on this scale. Species browsed less in proportion to the relative abundance would score less than one. For purposes of this calculation, all species present on a site were included for determining relative abundance, but those which were present on fewer than two sites, or which had fewer than 10 occurrences across all sites were not included in the listing of preferences calculated based on these results. A preference index was then created by subtracting the mean score from each species score. As a means of taking into account the greater confidence resulting from larger samples, the preference index was adjusted by multiplying the preference index by the number of plant hits of that species divided by ten. Finally, the index was adjusted by assigning all species with a proportional browse of between 1.5 and .5 a preference index of 0 under the assumption that they were browsed roughly in proportion to their occurrence and hence were neither preferred nor avoided by deer. This process resulted in a range of values from 50.14 to –21.57, with species having large positive preference indices being highly preferred, and those with large negative indices being highly avoided. See Table 2.

Presumably, sites that exhibit browsing on highly avoided species are likely to be located in areas with relatively high levels of deer impacts. It should be noted that certain species that are listed in this document as not being browsed, and hence being non-preferred or avoided, could in fact be preferred species. These plants may not have appeared as browsed because of total consumption of the plant, leaving no identifiable portion of the plant to be observed. In such cases those species may appear as unpreferred or avoided species because only unbrowsed individuals are identifiable. Particularly, Red Maple, which has been noted as highly preferred by deer in other literature (DeCalesta 1998), is not heavily browsed on the LTEM transects, but may be highly preferred at CVNP. In addition, seasonality of preferences may complicate analysis of preference rankings and changes in relative abundance.

While seasonality of preferences and compensatory growth exhibited by some species under browsing pressure may complicate matters, in general, the relative abundance of preferred species is expected to decrease in abundance over time, while that of avoided species is expected to increase under greater deer browsing pressure. To examine this possibility, the change in abundance of preferred and avoided plants on undefoliated forest sites was compared between high and lower deer impact sites.

All sites and levels of deer and gypsy moth impacts were examined for significant changes in other groundcover, vertical structure, and seedling regeneration variables between 1998 and 2001 (the "study period") by calculating the difference between the two years for each variable and using two way ANOVA. Statistical significance was indicated by a critical p-value of less than 0.10. (NPS 2002; see also Elzinga et. al. 1998). Because ANOVA is generally considered robust, deviations from parametric assumptions of normality were disregarded (Zar 1984). The statistical software used was Sigmastat 2.03.

B. SUMMARY OF PREVIOUS DATA ANALYSES

All 92 sites were first sampled in 1998. In the analysis of this one year's data, sites were stratified by habitat and deer density based on winter fecal pellet counts. Those sites with greater than one standard error above the average pellet count across all sites were considered high deer density areas, while all others were considered low deer density areas. Data showed wide differences between strata means for several variables: stocking, seedlings/ha, weighted seedlings/ha, height of the tallest seedling, and number of seedlings in taller height classes. However the variation around these means was so great that the differences failed to achieve statistical significance (significance was identified at that time by a p value <0.05). When data failed equal variance and normality tests, non-parametric tests were used, decreasing the power to detect significant differences.

Although results did not show significant differences in variables that were expected to be influenced by high deer densities (such as seedling regeneration variables, and native species diversity), a few significant results were observed for other variables. Herbs were significantly taller and organic litter abundance was significantly lower on high deer density upland forest sites versus low deer density upland forest sites. This result was attributed to a number of potential causes, including the probability of a false difference error, and deer induced changes in nutrient cycling. Another explanation, not identified in the initial reports, is that deer may be attracted to areas with more plants and taller plants for cover and forage. Another possible explanation is that winter fecal pellet count alone may not be a good indicator of deer impacts, as explained in the 2001 Cuyahoga Valley National Park Deer Exclosure Report (NPS 2002).

Other observations in 1998 included low seedling stocking throughout all strata. The USFS (USDA, Forest Service 1998[c]) recommended that at least 67% of plots per site be stocked with at least 30 seedlings to sustain high deer impact, and that at least 67% of plots per site be stocked with at least 10 seedlings to sustain low deer impact (based on weighted seedling counts). While some individual sites met these recommendations, strata averages did not. Because of the many factors that can influence seedling development, it could not be stated that deer browsing was the primary cause of low stocking observed throughout the Park without specifically excluding deer as an influencing factor and then measuring for improvement. This observation, among others, lead to the implementation of a quantitative deer exclosure study that closely mimicked the methodology used in this study by using the protocol to compare fenced and unfenced areas. The results of the first re-measurements of these plots are reported in NPS 2002.

In a supplemental analysis of CUVA's 1998 LTEM data the USFS found a relationship between local deer density, as estimated by the mean local pellet count over three years, and the height of the tallest seedling and weighted total seedling count at sample locations in the bottomland forests. At higher local (meaning site specific)deer densities, tallest seedlings were shorter than those found at lower local deer densities. While many factors can influence seedling height, local pellet mean explained 37% of the variance of that variable. Mean local pellet count explained 35% of the variance of the weighted seedling count variable.

In 1999, only bottomland forest LTEMS were measured in order to re-test the relationships between mean local pellet count and height of the tallest seedling and weighted seedling counts. Results for 1999 indicated that there remained a weak relationship between local pellet count mean and weighted seedling counts, but results were not statistically significant at $p<0.05$. Possible explanations included natural fluctuations of seedling mortality and fecundity, gypsy moth impact to the tallest seedling at one site, an increase in pellets at a previously zero pellet site, accidental loss of a site due to mowing, and overall low statistical power.

II. 2001 RESULTS AND DISCUSSION

Changes in forest vegetation during the study period were examined separately for upland and bottomland forests using two-way ANOVA, analyzing for both deer impacts and gypsy moth defoliation. If differences were in vegetation due to these factors, variables for which differences were detected were analyzed for inter-correlation with other variables that could explain spurious relationships with deer or gypsy moth defoliation. If no other potential causative factors were found, then the differences in that variable were ascribed to impacts of either deer or gypsy moth defoliation, as appropriate (NPS 2002). If correlations with possible causative factors were found, multiple linear regression was used to examine relative importance in explaining vegetation changes.

A. Upland Forests

Changes in upland forests that differed significantly between different levels of deer impact or defoliation are summarized in Table 3.

The mean deer fecal pellet count over three years at the LTEM sites in late winter/early spring did not differ significantly among different levels of deer or gypsy moth impacts. However, there were large differences between high and lower deer impact areas (based on change in height of the tallest seedling). High impact sites in upland forests averaged 11.6 pellet groups, while lower impact areas averaged 5.3.

As expected, the level of gypsy moth defoliation is significantly related to the percentage of basal area covered by oak and hickory trees, while different levels of deer impact were not related to this variable. On the high defoliation sites, an average of 70 percent of the basal area was composed of oaks and hickories. On the undefoliated sites, the average basal area of oaks and hickories was 19 percent. ($F_{1,61}$=3.953, p=0.013).

After accounting for the effects of defoliation, the level of deer impacts in upland forests was significantly related to: the number of seedlings per hectare in Height Classes A and B, total seedlings per hectare, weighted seedlings per hectare, stocking to sustain low and high deer impacts, number of red maple seedlings, abundance of reproductive plants, grass/sedge abundance, number of species, total plant abundance, and Shannon and Native diversity indices (see Table 3).

The change in percent canopy was also significantly different between high and lower deer impact areas. No correlation was found between height of the tallest seedling and canopy, which indicates that this difference does not account for the differences between these groups. In fact, the lower deer impact areas had increases in canopy, while the high impact areas had a slight decrease. The high impact sites had an increase in light penetration due to the reduction in percent canopy. Increased growth of seedlings would be expected under decreased canopy because of the increased light penetration. Because the high impact sites were classified as high impact sites based on a decrease in seedling height, canopy cover is not a confounding factor. If anything, the increased sunlight on the higher impact sites would be likely to mask the impacts of deer.

Gypsy moth defoliation was significantly related to abundance of reproductive plants and red maple seedlings, with moderately defoliated sites having much greater increases in reproductive plants compared to all other levels of defoliation.

Relationships among change in vegetation between 1998-2001 and levels of deer impact and gypsy moth defoliation in Upland Forests.

		Interactions Between Gypsy Moth Defoliation and Deer Impacts								Level of Gypsy Moth Defoliation				Level of Deer Impact	
		High Defoliation		Moderate Defoliation		Low defoliation		Undefoliated							
		High Deer (n=1)	Lower Deer (n=3)	High Deer (n=5)	Lower Deer (n=3)	High Deer (n=15)	Lower Deer (n=21)	High Deer (n=7)	Lower Deer (n=9)	H (n=4)	M (n=6)	L (n=36)	N (n=16)	High (n=26)	Lower (n=36)
MEAN	Percent Oak-Hickory	0.7000	0.7160	0.5410	0.4100	0.4440	0.3840	0.2300	0.1480	0.7080	0.4750	0.4140	0.1020	0.4810	0.4140
S.E.		0.2850	0.1430	0.1650	0.1650	0.0737	0.0623	0.1080	0.1010	0.1600	0.1160	0.0482	0.0738	0.0886	0.0620
MEAN	Height of tallest seedling	-7.000	70.750	-53.333	49.333	-60.735	-15.286	-61.429	31.125	31.875	-3.000	-38.010	-15.152	-46.124	33.981
S.E.		103.098	51.540	58.524	59.524	26.620	22.498	38.968	36.451	57.634	42.090	17.427	26.679	32.015	22.410
MEAN	Seedlings/ha A	-35013.000	2917.750	0.000	2122.000	-3607.400	4345.048	909.429	7692.250	-16047.625	1061.000	368.824	4300.839	-9427.743	4269.262
S.E.		15865.486	7932.743	9159.943	9158.943	4096.451	3462.135	5996.590	5609.286	8869.076	6477.058	2081.757	4105.565	4826.701	3448.582
MEAN	Seedlings/ha B	1061.000	11140.500	4244.000	6719.667	1131.735	1111.524	-757.857	1326.250	6100.750	5481.835	1121.629	284.196	1419.719	5074.485
S.E.		4039.701	2469.851	2851.938	2851.938	1275.425	1077.931	1867.032	1746.448	2781.377	2016.625	834.062	1278.269	1533.923	1075.712
MEAN	Total Seedlings/ha	-33952.000	15119.250	2829.333	9549.000	-2970.800	5305.000	-151.571	9283.750	-9416.375	6189.167	1167.100	4566.089	-8561.260	9814.250
S.E.		17010.456	8505.228	9820.991	9820.991	4392.081	3711.986	6429.348	6014.104	9509.134	6944.490	2875.292	4401.874	5282.248	3697.457
MEAN	Weighted Seedlings/ha	-32891.000	45092.500	-33952.000	26171.333	-15014.933	2020.952	-9700.571	16312.875	6100.750	-3880.333	-5406.990	3306.152	-22189.626	22399.415
S.E.		37690.852	18845.426	21760.823	21760.823	9731.736	8224.818	14245.803	13325.728	21069.827	15367.226	6370.000	9753.435	11704.121	8192.627
MEAN	Stocking to sustain low deer impacts	-24.000	-0.250	0.000	21.667	-2.467	6.190	-5.143	16.500	-17.125	10.833	1.862	5.679	-10.402	11.027
S.E.		29.323	14.661	16.930	16.930	7.571	6.399	11.083	10.367	16.392	11.971	4.956	7.588	9.106	6.374
MEAN	Stocking to sustain high deer impacts	-67.000	16.250	0.000	11.000	-13.533	6.286	-14.286	4.125	-25.375	5.500	-3.624	-5.080	-23.705	9.415
S.E.		24.453	12.226	14.160	14.118	6.314	5.336	9.242	8.645	13.670	9.983	4.133	6.228	7.593	5.315
MEAN	Red Maple Seedlings/site	-29.000	2.500	-6.000	-2.333	-0.667	1.810	0.571	2.375	-13.250	-4.167	0.571	1.473	-8.774	1.088
S.E.		5.053	2.977	3.437	3.437	1.537	1.209	2.250	2.105	3.328	2.430	1.006	1.541	1.840	1.204
MEAN	Reproductive hits	-1.000	5.750	5.667	22.330	-3.600	1.381	-2.286	2.750	2.375	14.000	-1.110	0.232	-0.205	8.054
S.E.		12.902	6.451	7.449	7.448	3.331	2.816	4.877	4.562	7.213	5.267	2.181	3.239	4.007	2.805
MEAN	Grass/Sedge hits	-8.000	9.250	3.667	4.333	5.000	-0.619	-3.714	-0.750	0.625	4.000	1.190	-2.325	-1.262	3.054
S.E.		5.888	2.944	3.399	3.399	1.520	1.285	2.225	2.083	3.291	2.404	0.995	1.524	1.838	1.280
MEAN	Shrub/sapling hits	7.000	29.500	8.000	23.000	13.333	2.952	-2.714	11.375	18.250	15.500	8.143	4.330	6.405	16.707
S.E.		15.675	7.838	9.050	9.050	4.047	3.421	5.925	5.542	8.763	6.399	2.650	4.056	4.868	3.407
MEAN	Number of Species	-7.000	10.250	2.000	6.667	2.067	1.238	0.857	2.000	1.625	4.333	1.652	1.420	-0.510	5.039
S.E.		4.625	2.312	2.670	2.670	1.194	1.009	1.748	1.635	2.585	1.888	0.783	1.197	1.436	1.005
MEAN	Percent Canopy	-4.333	7.833	2.667	-2.222	0.778	3.524	0.095	2.500	1.750	0.222	2.151	1.298	-0.198	2.909
S.E.		4.647	2.324	2.683	2.683	1.200	1.014	1.756	1.643	2.598	1.897	0.786	1.203	1.443	1.010
MEAN	Total Plant Hits	4.000	67.500	27.333	59.667	11.933	9.095	16.429	26.500	35.750	43.500	10.514	21.464	14.924	40.690
S.E.		34.198	17.099	19.744	19.744	8.830	7.463	12.926	12.091	19.118	13.961	5.781	8.850	10.620	7.434
MEAN	Shannon-Weaver Diversity Index	-0.086	0.250	-0.019	0.007	0.064	0.050	-0.033	0.098	0.082	-0.006	0.047	0.032	0.019	0.096
S.E.		0.174	0.087	0.101	0.101	0.045	0.038	0.066	0.062	0.007	0.071	0.020	0.045	0.054	0.038
MEAN	Native Diversity Index	-0.122	0.268	0.036	0.024	0.056	0.056	0.016	0.129	0.078	0.030	0.056	0.072	-0.001	0.117
S.E.		0.169	0.084	0.097	0.097	0.044	0.044	0.064	0.060	0.094	0.069	0.029	0.044	0.052	0.037

Highlighted cells signify significant differences ($p < 0.10$)

Table 3

i. Tree Regeneration

In CVNP, deer browsing is the primary limiting factor in height of tree seedlings (NPS 2002). Other causes of decrease in height include natural thinning of tall seedlings through competition with seedlings outside the plot, insect infestations, pathogens, and impacts of park visitors. When evidence of any of these potential causes is found on a site, it is recorded on site data sheets.

Changes in height of the tallest seedling were significantly different between high and lower deer impact areas due to the fact that this factor was used to assign the level of deer impact. There was no significant difference in height of the tallest seedling among different levels of gypsy moth defoliation.

The number of black cherry, white ash, hawthorn, and sugar maple seedlings did not differ significantly due to deer impacts or gypsy moth defoliation. There were large increases in black cherry over the study period, particularly in high defoliation areas, but the differences were not statistically significant.

The impacts of deer on some vegetation variables appear to be related to the level of gypsy moth defoliation present. In undefoliated lower deer impact areas, seedlings per hectare in classes A and B increased, differing non-significantly from the higher impact undefoliated sites, which showed a

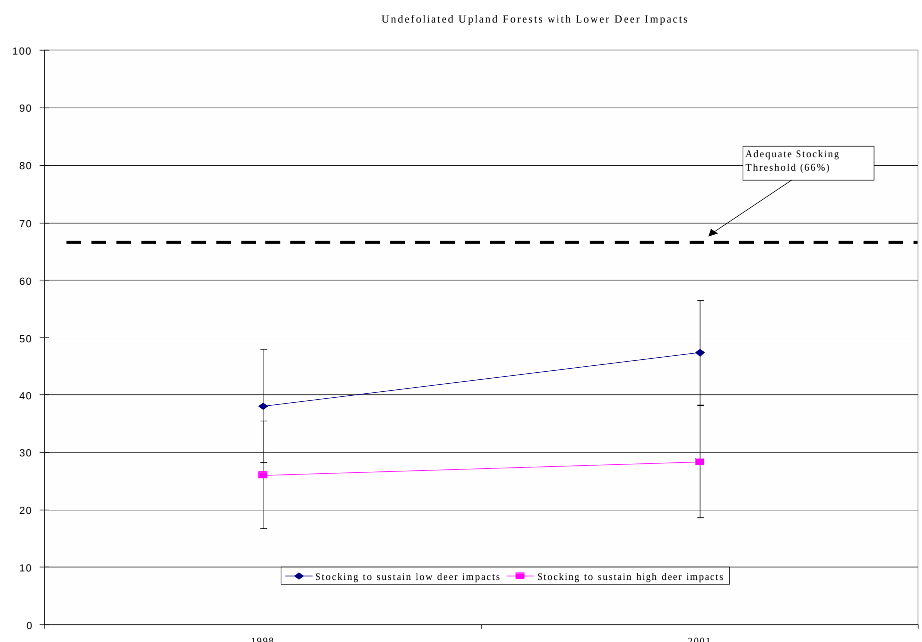


Figure 1

modest increase in the A class, and a decrease in the B class. On highly defoliated lower deer impact sites, the seedlings per hectare in the A and B classes increased, particularly in the B class. On highly defoliated high deer impact sites, the seedlings per hectare in Class B increased by approximately one thousand, while seedlings per hectare in Class A decreased by over 30,000.

While there did seem to be an interaction between defoliation and deer impacts with regard to the seedling variables discussed in the previous paragraph, seedling stocking levels seem to be significantly related to level of deer impact, but not level of gypsy moth impact. While stocking did not meet recommended levels in high or lower deer impact areas, the lower impact areas showed progress in advancing toward minimum stocking levels for both high and low deer impact thresholds, while the high deer impact sites showed decreased levels of stocking. (See Figures 1 and 2).

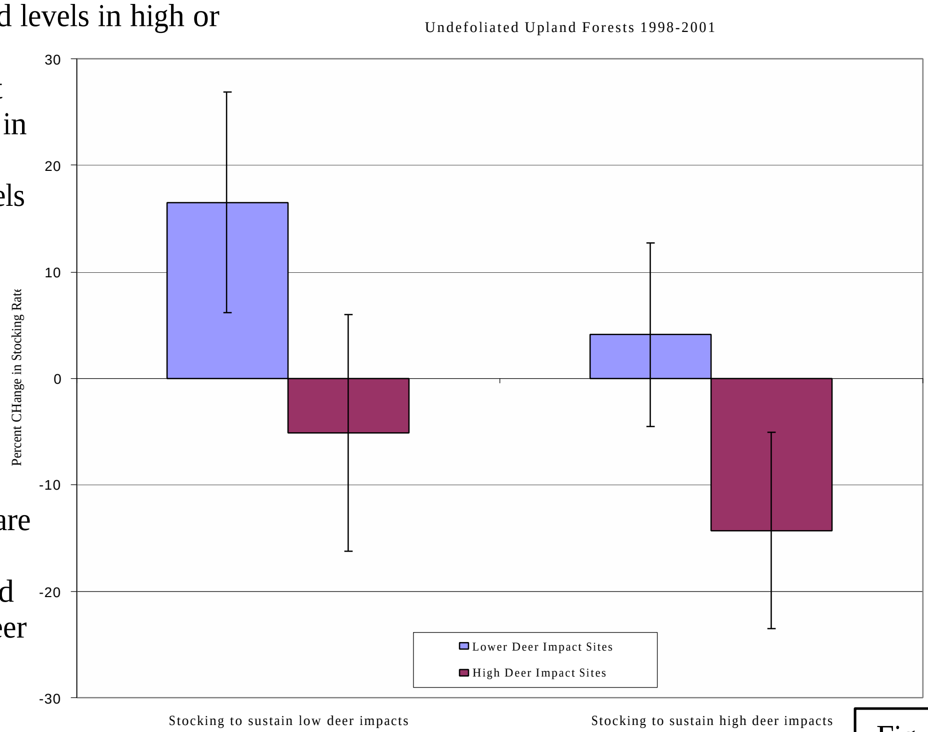


Figure 2

The data suggest deer are damaging the seedling recruitment, height, and stocking of the high deer impact upland forests, and that defoliation, while not completely counteracting the deer impacts, has to some extent moderated these impacts. In the lower deer impact undefoliated areas, seedling growth and numbers are consistent with the expected natural trend.

ii. Groundcover

In undefoliated areas, the amount of grass encountered on transects in both high and lower impact sites is decreasing, although it decreased at a significantly greater rate on the high deer impact sites. Under low defoliation however, the grass abundance increased on high impact sites while decreasing on lower deer impact sites. Under high defoliation, on high deer impact sites, the grass abundance decreased, while on lower impact sites, grass increased.

Lower impact sites with taller seedlings tend to have lower forb abundance ($r=-.270$, $p= .0878$). Also, in lower impact areas, sites with more forbs tend to have more total browse ($r=.365$, $p=.0190$).

In highly impacted areas, the 1998-2001 fecal pellet mean is significantly positively correlated with exotic plant abundance ($r=.847$, $p=<.0001$), and total plant abundance ($r=.479$, $p=.0443$) and negatively correlated with rock and organic litter abundance ($r=-.532$, $p=.0231$). In these same areas, sites with taller seedlings tend to have a higher percentage of plants browsed ($r=.600$, $p=.009$) as well as a greater amount of browse ($r=.575$, $p=.0125$). Sites with taller seedlings tend to have less grass/sedge abundance ($r=-.406$, $p=.0942$).

Under high deer impacts, the herbaceous cover and diversity indices tend to decrease under greater shade, while increasing along with increases in pellet count. This suggests that deer are attracted to areas with greater herbaceous cover, and hence possibly higher species diversity. This possibility is in line with the observation above that in high deer impact areas, the presence of more pellet groups is correlated with the presence of more plants.

A similar result was encountered with regard to shrub/sapling abundance. In undefoliated, lower deer impact areas, shrub/sapling abundance increased, while in undefoliated high deer impact areas, shrub/sapling abundance decreased slightly for a significant difference of approximately 14 hits per site on average. Under low defoliation, the lower deer impact areas saw modest increases in shrub/sapling abundance, while in high deer impact areas, the shrub/sapling abundance increased at a significantly greater rate. This difference between high deer impact sites and lower deer impact sites under high and low levels of defoliation suggests that deer adversely impact the shrub/sapling layer in CVNP, and that in the absence of defoliation, that impact would have been much more apparent. Gypsy moth defoliation seems to mitigate, at least in the short term, some of the adverse effects of deer on shrub/sapling vegetation in defoliated areas of the park. In high deer impact areas that are undefoliated, groundcover of shrub/saplings is decreasing while in all other upland forest areas, the shrub cover is increasing. The increase in shrub cover generally consisted of *Rubus spp*., *Rosa multiflora*, and *Viburnum acerifolium*. These shrubs were generally less than 30 centimeters tall, nearly always exhibited extensive evidence of deer browsing, poor vigor, and very sparse foliage.

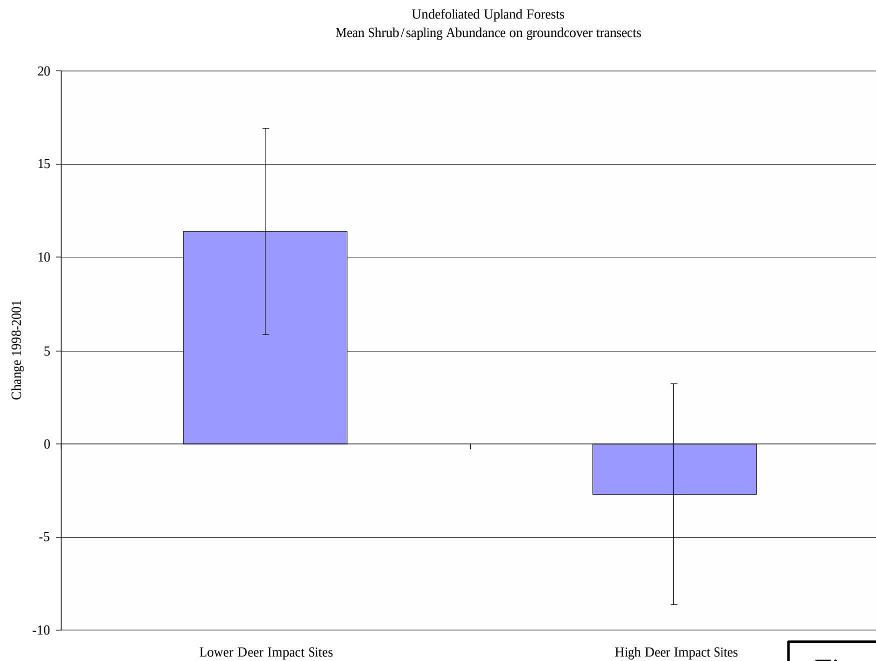


Figure 3

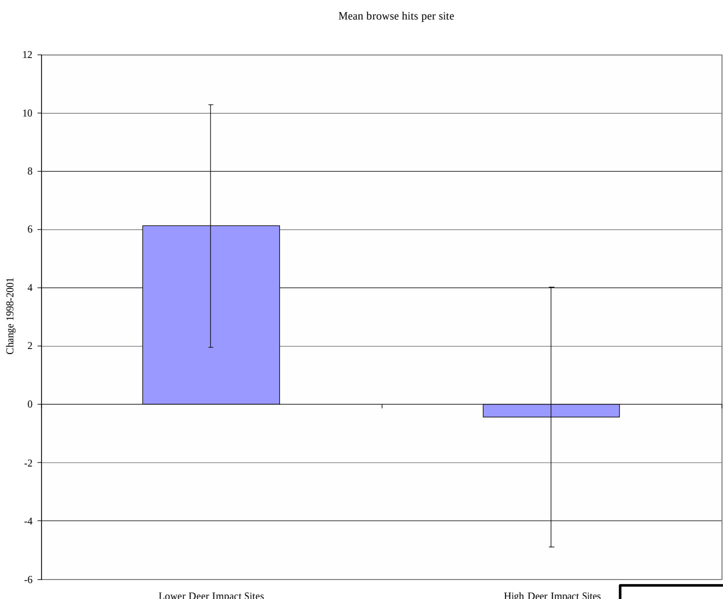


Figure 4

While the change in total browse did not differ significantly with the level of deer impact or defoliation, large differences were apparent. The lower deer impact sites saw an average increase of 11 browse hits, while the high impact sites averaged an increase of 4 hits. Browse appeared to increase as the defoliation intensity increased as well, with undefoliated sites increasing an average of approximately 3 hits per site, and high defoliation sites increasing by over 11 hits per site.

The Shannon and native diversity indices also displayed an interaction between defoliation and deer impact levels. In undefoliated lower deer impact sites, these indices increased, while on the undefoliated high impact sites, the Shannon diversity decreased, and the native diversity increased marginally. On the highly defoliated sites, both diversity indices increased vastly in the lower deer impact areas while decreasing on the high deer impact sites.

On undefoliated low deer impact sites, the number of species found increased, not significantly differing from the high impact undefoliated sites, which also showed an increase in the number of species present, although only half the increase of the lower impact sites. In contrast to this, the highly defoliated lower deer impact sites showed an increase of ten species per site, while the highly defoliated high deer impact sites lost an average of seven species.

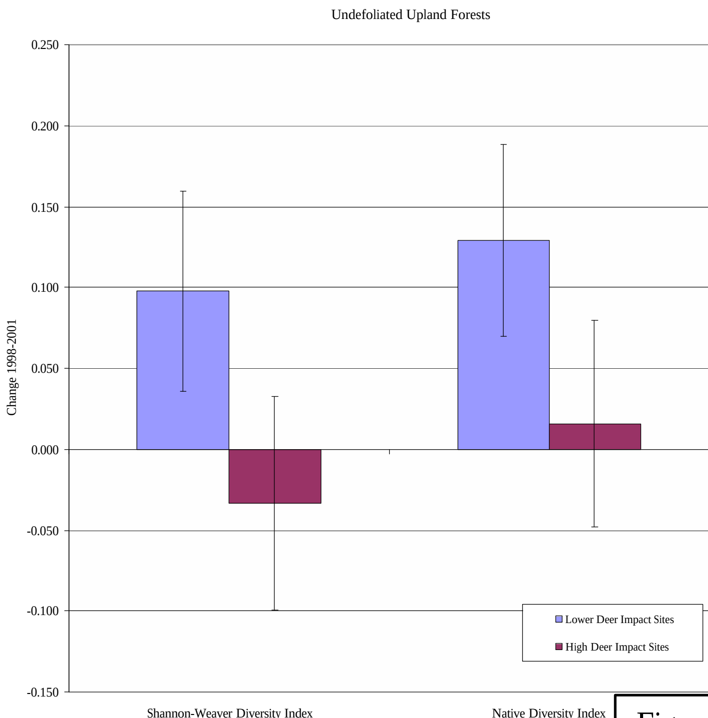


Figure 5

During correlation analysis to determine whether confounding factors were influencing this apparent difference in the diversity trend in high versus lower impact areas, it was discovered that native diversity was significantly negatively correlated with percent canopy (native: r=-.422, p=.0812; Shannon: r=-.390, p=.110) in the high impact areas, while in the lower impact areas, no such correlation was found.

In spite of this failure to find such a significant relationship in the lower impact areas, it was noted that in lower impact areas, native diversity is significantly and positively correlated with the height of the tallest seedling (native: r=.284, p=.0583; Shannon: r=.224, p=.139), while no correlation was found between canopy and Shannon or native diversity indices (p>.5 for both variables) in these areas. This suggests that there may be an interaction between shade and deer impacts which becomes apparent only above a threshold level of deer impact. Since this interaction is apparent in the high deer impact areas, but not in the lower impact areas, it is safe to assume that the threshold level of deer impacts is present when the height of the tallest seedlings has decreased due to deer browse.

After examining the significant differences in groundcover diversity, the question arose as to whether plant species preferred by deer were being adversely affected, or whether those avoided by deer were increasing, thereby affecting the overall diversity.

Because of differences in shade tolerance, only undefoliated sites were analyzed for differences in plant abundance between high and lower deer impact areas. There were no significant differences in abundance of either preferred or avoided species ($F_{1,14}$=1.203, p=0.293; $F_{1,14}$=1.303, p=0.274) between different levels of deer impacts. However, in high deer impact areas mean preferred plant abundance decreased slightly over the study period, while abundance of avoided species increased greatly. In lower deer impact areas, abundance of preferred plants increased, while abundance of avoided species decreased slightly.

This suggests that deer may be impacting the species composition of upland forest groundcover by selectively browsing on preferred plants. This may give avoided or non-preferred plants a competitive advantage. A long-term result of such a trend could be the elimination of preferred species.

iii. Vertical Structure

There were no significant differences in the total vertical foliage score, or vertical foliage scores at any height level, attributable to deer or gypsy moth impacts. The total vertical foliage score decreased between 1998 and 2001 in both the lower impact and high impact areas.

iv. Upland Forest Conclusions

In undefoliated upland forests with lower deer impacts, tree regeneration is increasing and approaching levels that will ensure continuation of forest cover in the event of overstory mortality. These areas are also increasing in shrub coverage, and groundcover diversity. These areas have an average three-year deer fecal pellet mean of 5.3.

In undefoliated upland forests with high deer impacts, tree regeneration, both in terms of number of seedlings, and stocking levels, is decreasing, as is shrub cover and groundcover diversity. These areas have an average three-year deer fecal pellet mean of 11.6, or nearly double that of the lower impact sites. On high impact sites, deer seem to be attracted to areas with more plant cover, and also browse more intensely in these areas.

Defoliation by gypsy moths tends to mitigate adverse impacts of deer on tree seedlings, shrubs, but exacerbate deer impacts to groundcover diversity in high deer impact areas.

B. Bottomland Forests

Relationships among change in vegetation between 1998-2001 and levels of deer impact and gypsy moth defoliation in Bottomland Forests.

		Level of Deer Impact		Level of Gypsy Moth Defoliation		Interactions Between Gypsy Moth Defoliation and Deer Impacts			
						Undefoliated		Low defoliation	
		Lower (n=7)	High (n=6)	N (n=7)	L (n=6)	Lower Deer (n=3)	High Deer (n=4)	Lower Deer (n=4)	High Deer (n=2)
Height of tallest seedling	MEAN	25.167	-22.233	3.100	-0.167	40.000	-33.800	10.333	-10.667
	S.E.	20.153	16.123	18.471	18.026	31.222	19.746	19.746	25.492
Forb hits	MEAN	-11.333	-9.500	-29.000	8.167	-37.000	-21.000	14.333	2.000
	S.E.	14.231	11.385	13.043	12.728	22.046	13.943	18.001	18.001
Vertical Foliage 1.5 M	MEAN	1.167	-1.733	0.100	-0.667	2.000	-1.800	0.333	-1.667
	S.E.	0.716	0.573	0.656	0.640	1.109	0.701	0.905	0.905
Total Plant Hits	MEAN	-15.750	-6.100	-25.850	4.000	-44.500	-7.200	13.000	-5.000
	S.E.	12.514	10.011	11.469	11.193	19.387	12.261	15.829	15.829
Exotic Hits	MEAN	-10.583	7.333	-16.250	13.000	-34.500	2.000	13.333	12.667
	S.E.	9.151	7.321	8.387	8.185	14.177	8.966	11.576	11.576
Shannon-Weaver	MEAN	0.183	0.050	0.184	0.049	0.293	0.076	0.074	0.025
	S.E.	0.032	0.026	0.029	0.029	0.050	0.031	0.041	0.041
Native Diversity Index	MEAN	0.164	0.088	0.174	0.077	0.262	0.087	0.065	0.088
	S.E.	0.038	0.030	0.035	0.034	0.059	0.037	0.048	0.048

Highlighted cells signify significant differences (p< 0.10)

Table 4

Changes in bottomland forests that differed significantly between different levels of deer impact or defoliation are summarized in Table 4.

Mean three-year fecal pellet counts did not differ significantly between high and lower impact areas, or among different levels of defoliation. Interestingly, the areas identified as lower impact had more pellet groups than the higher impact areas. This may indicate that lower impact areas, in spite of a higher deer density implied by the higher pellet count, are more resilient to deer impacts. Alternatively, it could indicate that deer are moving into lower deer impact areas after impacting the high impact areas, and hence the lower impact areas will become high impact areas over time. This is consistent with literature suggesting that deer feed over a "fluctuating network of foraging patches" based on resource quality and availability (Kohlmann & Risenhoover 1994).

i. Tree Regeneration

Height of the tallest seedling was not significantly different among the different levels of gypsy moth impact, although seedlings in areas with low defoliation tended to get slightly shorter, while those in undefoliated areas tended to get slightly taller. The significant difference between different levels of deer impacts is simply a reflection of the method used to classify the sites. Interestingly, there was a significant interaction between the level of deer impact and gypsy moth defoliation. In the undefoliated areas, there was a significant difference in the change in height between high and lower deer impact areas, while in the areas with defoliation, there was no significant difference between high and low deer impact areas, even in spite of the fact that this factor was used to determine which sites fell into each deer impact category. This may indicate that defoliation moderates the impacts of deer on the seedlings, that deer impacts moderate the effects of defoliation, or both. This may cause a masking effect in which deer impacts over time will not be easily identifiable until the effects of defoliation have been lessened with the passing of time.

In bottomland forests, there were no significant differences in the change in the number of seedlings per hectare in any height class due to either deer impacts or gypsy moth defoliation. The change in total seedlings per hectare was, however, positive in the lower deer impact areas, while negative in the high deer impact areas. In undefoliated areas, seedlings were generally lost over the study period regardless of whether the site was designated a high or lower deer impact area, while on sites with low levels of defoliation, lower impact areas gained seedlings and high impact areas lost seedlings. This suggests that low levels of defoliation are capable of counteracting some deer impacts on seedling numbers under lower deer impacts, while under high deer impacts, low defoliation levels while partially counteracting deer impacts to seedling numbers, do not completely eliminate the loss of seedlings due to deer impacts. The same trend is present in the change in the number of weighted seedlings per hectare, again, without reaching the level of statistical significance.

There were no significant differences in the stocking rates for either high or low deer impacts or different levels of defoliation, although the stocking rate for low deer impacts did increase by 13 percent in lower impact areas while the rate remained fairly static on the high impact sites, dropping only by one tenth of a percent. In the high deer impact areas, stocking for high deer impacts decreased by 5 percent, while it did not change in the lower impact areas. Both high and lower deer impact areas remain below recommended stocking thresholds.

There were no significant differences in the change in the number of white ash, sugar maple, red maple or black cherry seedlings due to either deer impacts or gypsy moth defoliation. However, on lower deer impact sites, there was an average increase of 1.5 black cherry seedlings, while on high impact sites, there was an average decrease of 7.33 black cherry seedlings.

There was significant inter-correlation among seedling variables, but Pearson correlation analysis did not reveal significant correlation with potential causative factors. There were, however, several correlations of interest in the high impact areas. The Shannon and native diversity indices are significantly and positively correlated with the height of the tallest seedlings (Shannon: r=.893, p=.016; Native: r=.858, p=.0286). This suggests that taller seedlings indicate greater diversity under high deer impacts.

On lower impact sites, there was no significant inter-correlation between height of the tallest seedling and the numbers of seedlings in various height classes, except for in class D, where there was significant correlation with the height of the tallest seedling (r=.937, p=.0018) due to the fact that many of the tallest seedlings were in this height class. There were, however, significant negative correlations between seedlings in the B and C height classes, and weighted seedlings per hectare, and the average deer fecal pellet count from 1998-2001 (Class B: r=-.750, p=.0521; Class C: r=-.787, p=.0357; weighted seedlings per hectare: r=-.826, p=.0222). This suggests that in lower impact areas, deer are having negative impacts on these factors while not impacting height growth significantly.

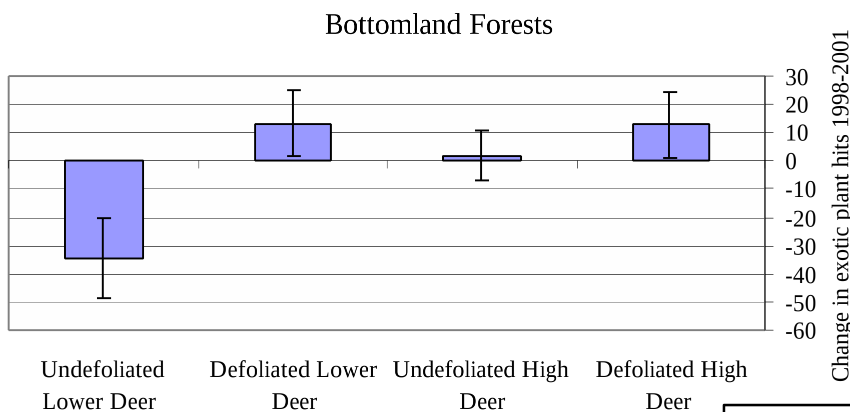


Figure 6

ii. Groundcover

Change in the abundance of forbs and total plants differed significantly based on the level of gypsy moth defoliation, while not differing significantly under different levels of deer impact. Undefoliated sites lost an average of 29 forb hits, while sites with low levels of defoliation gained an average of 8 forb hits. This indicates that regardless of the level of deer impact, in the absence of gypsy moth defoliation, bottomland forests are losing forb groundcover, while gypsy moth defoliation tends to stop this decrease.

There were no significant differences in the change in abundance of grass/sedge due to gypsy moth or deer impacts. However, there was a large difference between lower impact undefoliated sites, which lost 16.5 grass/sedge hits on average, and undefoliated high deer impact sites, which gained 5 grass/sedge hits on average. This might indicate that under higher levels of deer impact, the groundcover tends to increase in grass cover while decreasing in forb cover. Such a shift comports with preference data, which suggests that deer avoid browsing on grasses in forested areas of CVNP (See Table 2).

When examining differences in preferred and avoided plant relative abundance between high and lower deer impact sites, no significant differences were apparent ($F_{1,5}$=3.187, p=0.149; $F_{1,5}$=3.717,p=0.126). Interestingly, on both high and lower deer impact sites, avoided plants decreased in abundance, while preferred species increased. This indicates that at present, the deer may not presently be adversely effecting the relative abundance of groundcover. However, the shifting in abundance from avoided species to preferred species could be an indication that deer had in the past caused decreases in the abundance of preferred plants, and the relative abundance is now recovering following a temporary reduction in browse pressure due to recent widespread gypsy moth defoliation, which allowed increased light penetration and hence more forage production to occur across large areas of the park. Other possible explanations include compensatory growth by some species of preferred plants, as well as the invasive nature of two of the top three preferred plant species, *Ligustrum vulgare* and *Rosa multiflora*..

Change in the number of exotic hits per site differed significantly depending on the level of gypsy moth defoliation present. There was not a significant difference when comparing undefoliated high and lower deer impact sites. However, undefoliated lower impact sites averaged a loss of 34.5 exotic hits per site, while undefoliated high deer impact sites averaged a gain of two hits per site. On defoliated sites, both high and lower deer impact sites gained a similar number of exotic plant hits. These observations suggests that gypsy moth defoliation and high levels of deer impact both contribute to increases in the groundcover of exotic plants in the bottomland forests of CUVA.

Changes in Shannon diversity show significant differences based on the level of deer and gypsy moth impacts present, as well as a significant interaction between the two perturbations. On undefoliated sites under lower deer impacts, the Shannon diversity increased by .293, while on undefoliated high impact sites, it increased by only .0757. On defoliated lower deer impact sites, the Shannon diversity index increased by .074, while defoliated high deer impact sites had an increase of .0246. Native diversity shows similar changes.

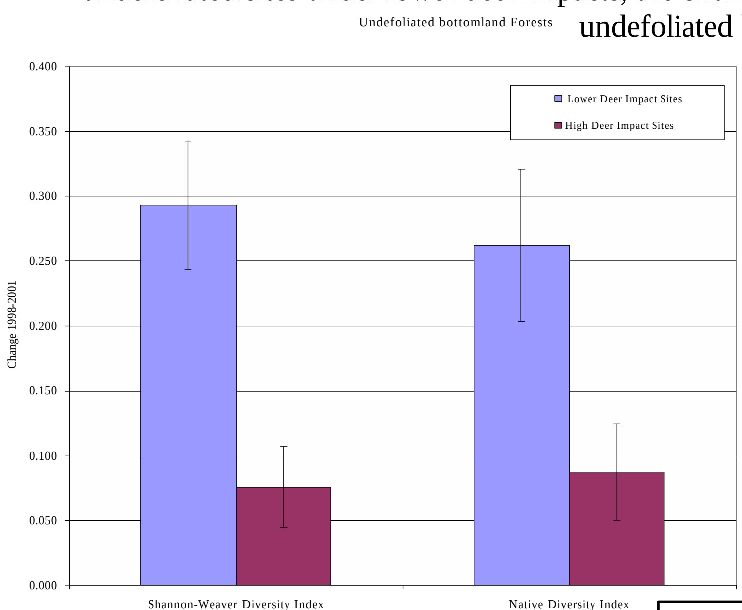


Figure 7

There were no significant differences in the change in the number of shrub/sapling hits, fern hits, seedling hits, or count of species over the study period. This lack of differences could be due to the fluctuating nature of deer feeding as some patches recover as others are browsed, small differences that may take a longer period of time before appearing significant, lack of impacts, or similarity of impacts on these variables between high and low deer impact areas.

iii. Vertical Structure

In the 1.5-2 meter vertical foliage class, the lower deer impact sites averaged an increase of 1.167, while the high deer impact areas averaged a loss of 1.733. There were no other significant differences in vertical structure between high and lower deer impact areas. There were no significant differences between different levels of gypsy moth defoliation.

While vertical structure showed no other statistically significant differences between high and lower impact sites, when examining interaction between variables, it became apparent that in the high impact areas, there was a significant negative correlation between percent canopy and vertical foliage score at the lowest height stratum (r=-.854 , p=.0306). This correlation was not apparent at other height levels, nor was there any correlation between canopy and vertical structure in the lower impact areas. This leads to the possibility that vertical structure is influenced negatively by deer under high levels of shade. To investigate this possibility, backward stepwise regression was conducted to determine whether deer related variables in conjunction with canopy could be identified which explained the variation present in the data. At the lowest height stratum, a combination of percent canopy and percent browsed explained 89 percent of the variation in that variable (r^2=.892, p=.035). At the B vertical strata, the same variables combined to explain 86 percent of the variation (r^2=.858, p=.054). At the C vertical strata, these same variables explained 77 percent of the variation, but not significantly so (r^2=.772, p=.109). At heights above 1.5 meters, no combination of canopy and percent browse produced significant results. This correlation implies that under more shaded conditions, deer adversely impact vertical structure in the high impact areas of bottomland forests of CVNP.

These relationships are not apparent in the lower impact areas, although there is a significant positive correlation between deer fecal pellet counts and vertical structure in the B, C, and D vertical strata (r=.689, p=.0866; r=.690, p=.0864; r=.77, p=.0427). This suggests that in lower impact areas, deer are either attracted to areas with more vertical structure, and thus more cover, or else deer enhance the growth of vertical structure under deer densities currently present in the lower impact areas.

vi. Bottomland Forest Conclusions

There were no significant differences between lower and high deer impact areas for tree regeneration variables. However, in the lower impact areas, higher numbers of deer pellets are associated with fewer seedlings in the B and C height classes, and fewer weighted seedlings. This indicates that while deer have already impacted the height growth in high impact areas, deer may be beginning to impact the seedling growth in the lower impact areas as well.
Both lower and high deer impact areas are losing herbaceous groundcover, except in areas of defoliation, which have gained herbaceous groundcover. Deer and gypsy moth impacts combine to contribute to increased groundcover of exotic plant species.

The percentage of deer browse and shade interact in the high deer impact areas to adversely impact the vertical structure of the forest, while in lower deer impact areas, more deer pellets are associated with increased vertical structure.

C. **Fields**

Fields were not analyzed for deer impacts due to the small number of lower deer impact fields available for comparison. The significant changes in the fields over the study period as indicated by paired t-tests are as follows (n=15 for all variables). Browse hits increased by an average of 17 hits per site (t=3.603, p=.003). Percent browse increased by an average of 6 percent (t=3.653, p=.003). Abundance of reproductive plants increased by an average of 21 hits per site (t=3.649, p=0.003). Abundance of grasses and sedges decreased by an average of 13 hits per site (t=-1.755, p=0.101). Shrub and sapling hits increased by an average of 34 hits per site (t=2.789, p=.014). Vertical foliage A decreased (t=-3.014, p=.009). Shannon diversity increased (t=4.156, p<0.001), as did native diversity (t=4.706, p=<0.001).

Vertical structure is expected to increase over time, but was observed to be decreasing, at least in the lowest stratum. Other than this, the other significant changes seem to be in a direction that would be expected as fields continue to undergo succession.

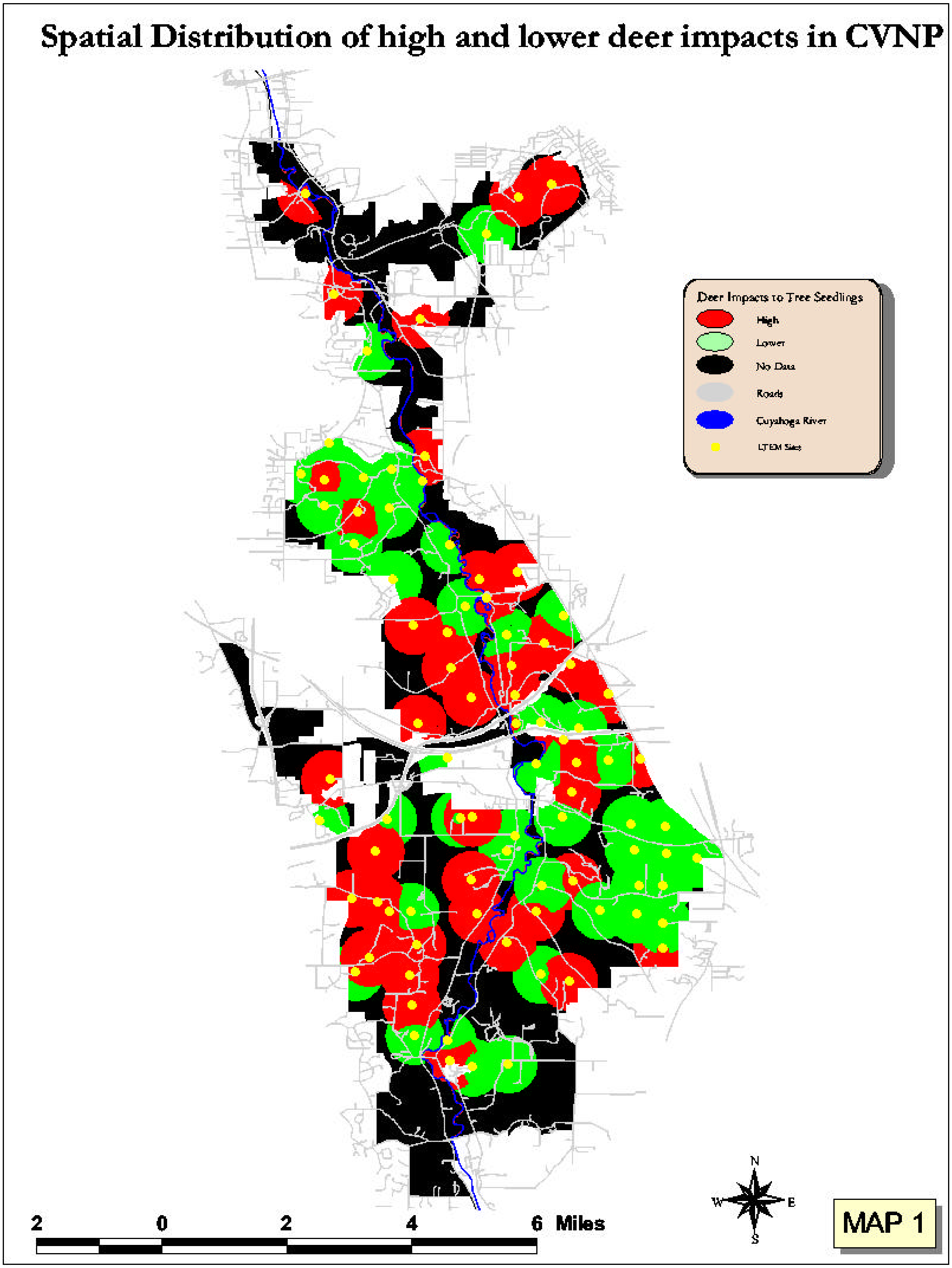
III. Spatial Interpretation of Deer impacts to the Vegetation of CVNP

MAP 1 shows areas of high and lower deer impacts to seedling height within the boundary of CVNP. The map was modeled through interpolation of data between sample points under the assumption that similar impacts would be expected to the area encompassed in an average sized deer home-range centered on the sample point. For this report, the average range of deer is assumed to be the area represented by a 1.5 km diameter circle. This assumption is based on literature suggesting deer home ranges in suburban areas average 50ha (Connicelli 1992) and in more agricultural areas can average about 170ha (Vercauteren and Hyngstrom 1998). Since deer in areas that are more agricultural than CUVA typically have larger home ranges, typical home ranges in the park are expected to not exceed ~170ha, which is approximately the area encompassed in a 1.5 km diameter circle.

The average difference in height of the tallest seedlings between years (after taking into account non-deer related decreases as explained above) was calculated and interpolated for each cell in a grid covering the park. If the average height change was zero or negative, the area was tagged as a high impact area, while those displaying some positive growth in the height of the tallest seedling were tagged as lower impact areas. Areas appearing as black are areas in which no monitoring plot was placed close enough to determine the level of deer impacts. This lack of data occurs because the LTEM points were not selected with the thought of this type of analysis in mind, as well as because no sites were placed on private property, which limited the ability to take measurements in some areas of the park.

Assuming no major changes in deer distribution or density, the areas identified as high impact areas would be expected to have fewer seedlings, fewer seedlings in taller height classes, lower seedling stocking, Shannon and native diversity indices which are expected to decrease over time, and decreasing vertical structure in bottomland forested areas with greater levels of shade.

Lower impact areas on the accompanying map are expected to have increasing numbers of seedlings, greater seedling stocking rates, increasing levels of Shannon and native diversity, decreasing levels of vertical structure. In lower impact areas, preferred plants are expected to increase or remain stable over time, while in high deer impact areas, preferred plants may decrease over time. When interpreting the accompanying map, it is important to realize that the interpolated approach used here paints with a broad brush. Portions of the area depicted as "Lower Impact" will be high impact areas, based on the local conditions prevalent on the site. Likewise, "High Impact" areas will certainly have within them localized sites with relatively low impacts.



In both uplands and bottomlands, as deer continue to browse, reducing the height and number of seedlings, they are likely to move from high to lower impact areas as resources are depleted. This possibility indicates that current lower impact areas may be subjected to greater deer impacts in the future, and may have been high impact areas in the past.

IV. Timing sequence of Impacts and Recovery in Forests

Based on information in this and other reports, a preliminary sequence of deer impacts may be constructed. First, deer impacts are the highest and appeared first in the bottomland (USDA 1998[b]). The first widespread impacts are either decreases in vertical structure or decreases in groundcover diversity. These impacts are followed by decreases in the height of the tallest seedlings, followed ultimately by significant decreases in seedling numbers, and possibly alterations in seedling species composition.

This sequence may be followed in the upland forests as well. The recent Deer Exclosure Report (NPS 2002) noted that there were no significant differences in seedling height or numbers, but there was a significantly lower rate of increase in groundcover diversity in the upland forests. This could indicate that the groundcover diversity is impacted before differences in seedlings become significant.

This possibility, reinforced by the data analyzed in this study makes it likely that groundcover is impacted before seedling height. The fact that there were small but non-significant increases in vertical structure in the exclosures, but decreases in vertical structure on unfenced plots in the exclosure study suggests that deer adversely impact vertical structure. Vertical structure is declining in both lower and high deer impact areas of the park. This suggests that the vertical structure is impacted before seedling height growth is adversely impacted. This stands to reason, as vertical cover consists of both herbaceous and woody species, and is predominantly seedlings and shrub species in the heights relevant to analyzing deer impacts.

The data collected in the current study indicated that in high deer impact uplands, there are fewer seedlings. The sites designated as high deer impact were so designated based on the fact that seedling growth had not progressed over the study period. Hence either concurrently with or shortly before or after seedling height growth is arrested, seedling numbers begin to drop.

Recovery from deer impacts is likely to depend on the level of impact currently present on a site. For example, groundcover diversity on upland forest sites showed significant gains after only two years of release from browse pressure in the exclosure study, while in the bottomland sites, no difference in diversity was noted between diversity on fenced and unfenced plots. The seedling height growth differed significantly between fenced and unfenced plots in the bottomland forests, suggesting that so long as all seedlings are not eliminated from a site, seedling growth recovers quickly from browse if the browsing pressure is lifted. Seedling numbers may then begin to recover as well. It is likely that vertical structure will recover only as seedling height and numbers increase.

Future re-measurements of the exclosures will shed light on the time period needed for groundcover diversity recovery on sites where the seedling height growth has been arrested. For the present it may be assumed that groundcover diversity will recover after the seedling height and numbers but concurrently or after the vertical structure.

V. Conclusions and Recommendations

The data from forests suggests that once damage to the height growth of seedlings occurs on a site, seedlings, vertical structure and groundcover diversity are impacted as well. Sites with high impacts should be considered areas in which groundcover diversity, vertical structure and tree regeneration are already impacted. Lower impact areas as identified by the change in height of the tallest seedling should be considered areas in which seedling height and numbers are not unacceptably impacted, but in which vertical structure is impacted in relation to the percent age of browse and the amount of canopy cover. These areas seem to be increasing in groundcover diversity, but this may be due to short-term effects of gypsy moth defoliation. Hence the groundcover diversity in these areas should be considered at risk for unacceptable impacts.

The areas identified as High and Low deer impact areas should be mapped in conjunction with the 2001 and 2002 deer distribution and density data when available. This may shed light on the deer densities associated with the characteristics of each of these areas. Means of preventing and ameliorating excess deer damage to the natural vegetation and plant communities of CVNP should also be explored. Variables should continue to be measured on a three-year cycle.

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